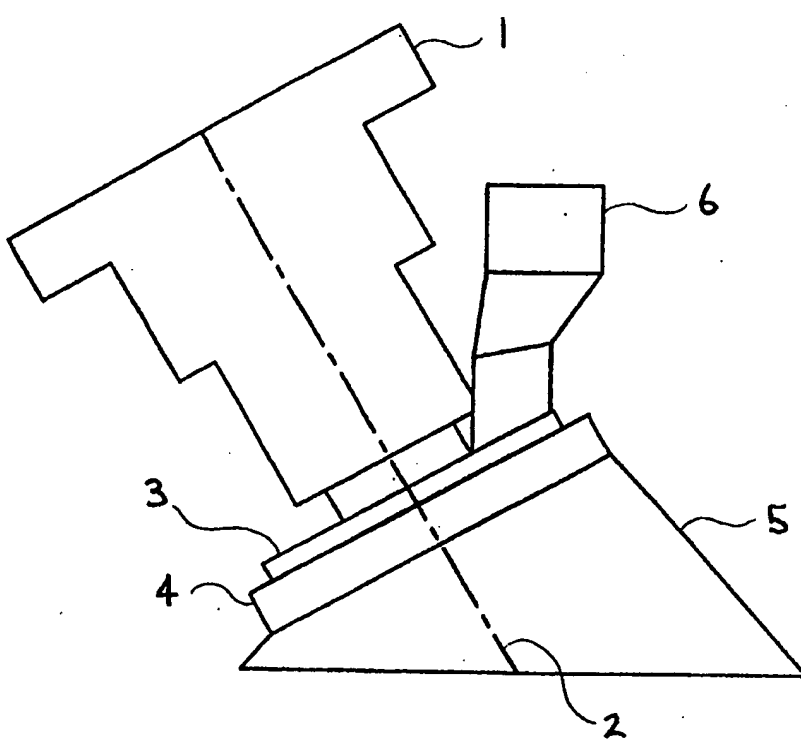


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<p>(54) Title: LASER CUTTING AND JOINING A FLUORINATED POLYMER MEMBRANE TO A POLYMER FRAME</p> <p>(57) Abstract</p> <p>Method and apparatus for cutting a fluorinated polymer membrane and simultaneously joining it to a polymer frame. The method comprising the steps of: (i) contacting a fluorinated polymer membrane with a polymer frame at the point where a cut and join is desired, and (ii) directing at least one laser beam onto the point of contact between the membrane and the frame so as to cut the membrane and effect a join to the frame.</p> 		

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## LASER CUTTING AND JOINING A FLUORINATED POLYMER MEMBRANE TO A POLYMER FRAME

The present invention relates to a method for cutting a fluorinated polymer membrane and simultaneously joining it to a polymeric supporting frame. Such a method may be useful in processes for the manufacture of filters, heat exchangers and electrochemical devices. In the latter case, the supporting frame may further comprise an electrode attached thereto so that the resultant frame/electrode/membrane combination forms a sub-assembly which may then be stacked together with other identical sub-assemblies to form an array of electrochemical cells, each cell thus comprising two bipolar electrodes with a membrane positioned therebetween so as to define separate anolyte-containing and catholyte-containing chambers within each cell. Such assemblies are well known to those skilled in the art and they may be used as fuel cells, electrolyzers and secondary batteries.

The incorporation of a polymeric membrane onto a supporting frame must satisfy a number of requirements. Firstly, the membrane must be accurately cut to the correct shape so that it fits the shape of the supporting frame. Secondly, the membrane must be accurately positioned on the supporting frame and its position must be verified as being correct prior to its attachment to the supporting frame. This second requirement becomes especially difficult to achieve as the size of the membrane and frame increases. The membranes are often very thin making them difficult to handle. Preferably, the first and second requirements are satisfied simultaneously by cutting the membrane in situ. Thirdly, the membrane must be attached to the supporting frame with sufficient strength to allow handling of the complete sub-assembly, for example, during stacking to form an array of electrochemical

cells.

More particularly, the present invention relates to a method for the attachment of a fluorinated polymer ion-exchange membrane onto a polymeric supporting frame. The supporting frame is preferably made of a single polyolefin polymer. This creates particular problems with regard to the requirements outlined above. With regard to the third requirement, the physical and chemical characteristics of fluorinated polymer ion-exchange membranes are very different from those of hydrocarbon polymers thus making it difficult to attach the two together. Fluorinated polymer ion-exchange membranes are not thermoplastic polymers, in contrast to simple hydrocarbon polymers. They are also hydrophilic, whereas hydrocarbon polymers are hydrophobic. These types of membranes can also be sensitive to humidity which places additional constraints on the cutting and aligning requirements of the method, i.e. these requirements must be satisfied quickly with minimum handling of the membrane. Another problem arises when the sub-assembly is to comprise a fluorinated polymer ion-exchange membrane. The chemical and physical properties of these membranes allow chemical species to wick through their thickness to the edges where they may leak out into unwanted areas of the sub-assembly causing both a loss of electrolyte and resultant contamination of the surroundings of the cells. Thus the edges of the membrane should preferably be de-functionalised in some way so as to prevent this wicking effect.

Known methods for cutting the membrane to the required shape include the use of a cutting die formed into the required shape, or the use of cutting knives of various types. However, especially as size increases, these methods are often not suitable for simultaneous aligning of the cut membrane on the

frame, i.e. in situ cutting. Accordingly they require further handling of the membrane in order to position it prior to attachment to the frame.

Furthermore, they involve physical contact between  
5 cutting edges and the membrane which may result in misalignment of, or damage to, the membrane.

Known methods for monitoring the correct alignment of the cut membrane on the supporting frame include the use of a laser triangulation system,  
10 however this is a costly and cumbersome technique. As mentioned above it would be preferable to use a method which allows cutting of the membrane in situ. This would obviate the need for the extra steps of aligning the membrane on the frame and then checking that the  
15 alignment is correct.

A number of methods are known for attaching a fluorinated polymer membrane onto a polymeric frame. Plastic rivets may be used to create a permanent mechanical attachment to the frame. However, this  
20 method suffers from the disadvantages that it involves the extra step of punching holes in the membrane and it also results in local attachment only. Glues such as those based on silane compounds may also be used. However, the differing chemical properties of the  
25 fluorinated polymer membranes and frame polymers to which the present invention is particularly directed mean that selection of a glue which is compatible with both materials is very difficult. Furthermore, when the method of the present invention is directed toward  
30 the manufacture of sub-assemblies for forming electrochemical cells, it is preferable that the glue selected be chemically stable in the aggressive chemical environments commonly found in such electrochemical cells. Welding of the two polymers by  
35 melting them in the vicinity of the desired point of attachment is also known but is again unsuitable for the fluorinated polymer ion-exchange membrane and

frame polymers to which the present invention is particularly directed because of their different thermal responses.

5 The wicking problem associated with the use of polymeric ion-exchange membranes may be addressed by the application of fluorinated greases to the edges of the membrane, however, this is a messy and unreliable solution.

10 It would be advantageous to achieve a method for the attachment of a fluorinated polymer membrane onto a polymeric supporting frame which addresses all the requirements outlined above simultaneously.

15 Accordingly, the present invention provides a method for cutting a fluorinated polymer membrane and simultaneously joining it to a polymer frame, the method comprising the steps of;

- (i) contacting a fluorinated polymer membrane with a polymer frame at the point where a cut and join is desired, and
- 20 (ii) directing at least one laser beam onto the point of contact between the membrane and the frame so as to cut the membrane and effect a join to the frame.

25 The present method allows cutting of the membrane to take place in situ, thus obviating the need for subsequent alignment of the cut membrane on the frame prior to joining. Furthermore, the use of a laser to cut the membrane is surprisingly found to simultaneously effect a join between the edge of the  
30 membrane and the frame. The join is found to be of sufficient strength and durability to allow subsequent handling of the membrane/frame sub-assembly.

35 Examples of fluorinated polymers, membranes of which may be cut and simultaneously joined to a polymer using this method, include polytetrafluoroethylene, polyhexafluoropropylene, tetrafluoroethylene-hexafluoropropylene copolymer,

tetrafluoroethylene-propylene copolymer,  
tetrafluoroethylene-ethylene copolymer,  
hexafluoropropylene-propylene copolymer  
hexafluoropropylene-ethylene copolymer, polyvinylidene  
5 fluoride, vinylidene fluoride tetrafluoroethylene  
copolymer, vinylidene fluoride hexafluoropropylene  
copolymer, polyvinyl fluoride, tetrafluoroethylene-  
perfluoroalkyl vinyl ether copolymer, polyvinylidene-  
hexafluoropropylene copolymer,  
10 chlorotrifluoroethylene-ethylene copolymer,  
chlorotrifluoroethylene-propylene copolymer, or  
perfluoroalkoxy copolymer.

In a preferred embodiment of the present  
invention the fluorinated polymer membrane is a  
15 fluorinated polymer ion-exchange membrane and even  
more preferably the fluorinated polymer membrane is a  
fluorinated polymer cation-exchange membrane.  
Fluorinated polymer ion-exchange membranes may be  
formed from any of the fluorinated polymers described  
20 above with suitably functionalised monomer units  
grafted thereon. Suitably functionalised monomer units  
are well known to those skilled in the art and their  
structures are variable, however they essentially  
comprise an unsaturated functional group such as a  
25 vinyl group and an ion-exchange group such as a  
sulfonate or carboxylate group. Preferably the  
membrane is a hydrolysed copolymer of  
tetrafluoroethylene and a perfluoro-vinyl ether  
monomer comprising a cation-exchange group. Examples  
30 of preferred cation exchange membranes include  
copolymers of tetrafluoroethylene and a sulfonated or  
carboxylated perfluoro-vinyl ether such as those sold  
under the trade names of Nafion (Du Pont), Flemion (Asahi  
Glass) and Aciplex (Asahi Chemical).

35 Preferably, the thickness of the membrane is in  
the range of from 25 $\mu$ m to 300 $\mu$ m, more preferably from  
30 $\mu$ m to 200 $\mu$ m, even more preferably from 50 $\mu$ m to

150 $\mu$ m.

It is possible that the membrane to be attached to the frame may also comprise an electrode attached thereto. Such membrane/electrode assemblies are well known in the art and all references to a membrane in this specification are intended to include such assemblies.

It will be appreciated that the polymeric frame may be formed from a wide range of polymers or copolymers. Suitable polymers include those selected from polyethylene, polypropylene, polystyrene and copolymer blends of two or more of polyethylene, polypropylene and polystyrene, acetal, nylons, polyethylene terephthalate, polyvinylidene fluoride, polyvinyl chloride, polytetrafluoroethylene, fluorinated ethylene-propylene copolymer, polyfluoramide, chlorinated polyoxymethylene and many others. The selection of a hydrogenated polymer frame material is particularly advantageous. This is because pyrolysis of perfluorinated polymers carries with it the possibility of the formation of perfluorisobutene (PFIB) which is highly toxic. Co-pyrolysis with hydrogenated material is found to produce little or no PFIB. It is believed that this is due to the rapid addition of hydrogen radicals to fluorocarbon radical intermediates formed by fluorocarbon degradation, thus preventing recombination of fluorocarbon radicals to yield PFIB.

When the fluorinated polymer membrane is an ion exchange membrane the present method not only cuts the membrane and simultaneously joins it to the frame but surprisingly is also found to effect de-functionalisation of the cut edge of the membrane. The term de-functionalisation is intended to mean that the nature of the ion exchange membrane is altered in some way so that it no longer exhibits the same characteristics. In particular, it means that chemical



species are no longer able to wick through the thickness of the membrane. The de-functionalisation of the membrane can be confirmed by staining the membrane with methylene blue which is a cationic dye. The de-functionalised region is not stained by the dye whilst the unaffected region is stained a deep blue colour. Thus, the problem of wicking associated with the use of such membranes is also addressed by the method of the present invention.

It will be understood that the laser source may be selected from a number of different types of laser and that the laser beam may be either pulsed or continuous. Preferably however the laser used is a pulsed CO<sub>2</sub> laser because the wavelength of light generated by this laser is particularly suitable for cutting the preferred polymer membranes mentioned above.

It will also be appreciated that the power of the laser beam to be used and the cutting speed achievable are interrelated and also dependent upon other parameters, in particular, upon the chemical structure and the thickness of the membrane. However, for the purposes of cutting the preferred polymer membranes mentioned above which are of a thickness in the range of from 25 $\mu$ m to 300 $\mu$ m the power of the laser beam is preferably in the range of from 10W to 150W and the cutting speed is preferably in the range of from 10mm/s to 1000mm/s, more preferably from 20mm/s to 500mm/s, even more preferably from 50mm/s to 200mm/s and most preferably from 100mm/s to 200mm/s.

The focus of the laser beam may also be varied, depending upon the other set-up parameters, so as to provide a broader or narrower width of irradiation of the membrane along the line of the cut/join. Preferably the width of the beam as it impinges on the membrane is in the range of from 50 $\mu$ m to 450 $\mu$ m, more preferably from 250 $\mu$ m to 400 $\mu$ m. Depending on the

identity of the materials being used it is sometimes found that for a given beam power, a narrower, i.e. more focussed, beam will provide a faster cutting speed but a weaker join whilst a wider, i.e. more diffuse, beam will provide a stronger join but at a slower cutting speed. A wider beam also aids the physical separation of the functional membrane from the scrap membrane. A narrow beam allows a faster cutting speed but ease of physical separation of the functional membrane from the scrap membrane is sacrificed. The present invention is not necessarily limited to the use of a single laser beam and it will be appreciated by those skilled in the art that other beam arrangements such as a dual beam or concentric multiple beams may also be employed. In particular the dual beam method may comprise one type of beam for providing a fast cut together with another type of beam for providing a stronger join.

The cutting process as performed by the method of the present invention often generates debris which, if not controlled, could contaminate the membrane and/or frame surfaces. Accordingly, in a preferred embodiment, the method of the present invention involves use of a shielding means which is situated adjacent to the point of contact of the laser beam with the membrane and which moves in synchrony with the laser beam as it travels along the cutting line. The shielding means thus prevents debris from contaminating areas around the cutting line.

In order for the method described above to effect a join between the fluorinated polymer membrane and the polymer frame it is essential that there be contact between the membrane and the frame at the point of cutting. The contact between the membrane and the frame may be achieved by pressure means which urges the membrane into contact with the frame at the point of cutting. Suitable pressure means may comprise

a plate of substantially the same perimeter size and shape as the membrane. The plate can be pressed against the membrane to ensure contact between the membrane and frame at the point of cutting. Such a  
5 plate may also be advantageously employed in combination with other types of pressure means because it provides the additional benefit of shielding the major central portion of the membrane from debris generated by the cutting of the membrane. Suitable  
10 pressure means may alternatively comprise a roller which impinges on the membrane at a position adjacent to the laser beam, or one or more air jets which apply positive gas pressure on the membrane at a position adjacent to the laser beam, or means for providing a  
15 vacuum between the membrane and the frame at or adjacent to the point where the laser beam impinges on the membrane.

In a particularly preferred embodiment, suitable pressure means may be provided by applying positive  
20 air pressure, such as an air jet, to a point adjacent to the point where the laser beam impinges on the membrane so as to bring the membrane and substrate polymer into physical contact. Preferably, the laser beam and the positive gas pressure are directed at an  
25 angle of from 110 to 120 degrees to the plane of the membrane, pointing in a direction away from the centre of the membrane. The use of positive gas pressure not only provides suitable pressure means to bring the membrane and substrate polymer into physical contact.  
30 The positive gas pressure also aids the lifting of the waste membrane whilst minimising the removal effects upon the functional piece of membrane. It also helps to remove fumes produced by the process from the vicinity of the membrane and frame.

35 The present invention also encompasses within its scope apparatus for performing the method of the present invention, said apparatus comprising a beam

delivery system which comprises means for generating and directing one or more laser beams onto the membrane and means for generating and directing positive gas pressure to a point at or adjacent to the point where said one or more laser beams impinge on the membrane.

The lasering operation may produce large volumes of fumes and therefore, in a preferred embodiment, the apparatus also comprises a cowl which encompasses the laser beam delivery area and an extraction device for conveying fumes away from the point of cutting and joining. Said cowl is preferably shaped such that the eccentric profile allows capture of the positive air pressure's 'bounced' trajectory.

In a preferred embodiment the means for generating and directing one or more laser beams and the means for generating and directing positive gas pressure are constructed so as to provide a laser beam and a gas jet which are substantially parallel to one another.

When the cutting and joining method follows a path which is not linear, the orientation of the beam delivery system must change relative to the membrane during the cutting and joining process. Therefore, when present, the orientation of the cowl must also change to maintain a uniform void between the cowl and the membrane so as not to drastically alter the dynamics of the fume transfer. Thus, in a preferred embodiment, the extraction device and the beam delivery system are mounted on a central boss, (through which the fumes may be removed) said boss being housed within a bearing on which the main body of the cowl may be mounted. The rotating portion of the cowl is preferably counterbalanced so as to allow the cowl to remain flush relative to the membrane regardless of the boss position.

The present invention also includes within its

scope a sub-assembly comprising a polymer frame and a fluorinated polymer membrane which has been cut and attached thereto by the method described above and also a stack of one or more such sub-assemblies arranged so as to form an array of electrochemical cells for use as a fuel cell, electrolyser or secondary battery.

The present invention will be further described with reference to Fig 1 which represents apparatus for performing the method of the present invention.

Referring to Fig 1, the apparatus comprises a beam delivery system (1) which in turn comprises means for generating and directing one or more laser beams and means for generating and directing positive gas pressure. The broken line (2) indicates the direction of the laser beam and gas jet generated by the beam delivery system. The beam delivery system is mounted on a central boss (3) which is housed within a bearing (4). A cowl (5) is attached to the bearing (4). Also mounted on the central boss (3) is a connection (6) to an extraction device which draws fumes from within the cowl (5) and removes them to an air purification system (not shown).

The present invention will be further described with reference to the following examples:

#### Example 1

Laser cutting and joining of membranes to a polyethylene substrate was carried out on the following membrane materials:

Flemion SH80 (80 $\mu$ m thick, dried unconstrained)  
Flemion SH80 (80 $\mu$ m thick, dried constrained)  
Nafion 115 (125 $\mu$ m thick)

The laser used was a Coherent Diamond 64 pulsed CO<sub>2</sub> industrial laser (power range 10-150 watts, optimum focal distance 5mm), mounted on a gantry motion system. The following parameters were used for cutting.

Pulse On-Time	25 $\mu$ s
Maximum Pulse Power	10%
Minimum Pulse Power	5%
Laser-Membrane Dist.	5mm
Cutting Speed	50mm/s

Each membrane was laid over a flat polyethylene substrate and cut in a straight line in directions both parallel to and orthogonal to the material axis. The results are summarised in the table below:

Material	Cut direction	Clean Cut?	Bonded?
Flemion SH80-constrained	Parallel	Yes	Yes
	Orthogonal	Yes	Yes
Flemion SH80-unconstrained	Parallel	No	Partially
	Orthogonal	Yes	Yes
Nafion 115	Parallel	Yes	Yes
	Orthogonal	Yes	Yes

The membranes were also cut in curved lines with identical results.

#### Example 2

A further test using the method of example 1 was carried out on Flemion SH80 material using the following laser set-up parameters:

Pulse On-Time	25 $\mu$ s
Maximum Pulse Power	100%
Minimum Pulse Power	80%

Laser-Membrane Dist. 5mm  
Cutting Speed 1000mm/s

The membrane was successfully cut and bonded.

5

### Example 3

A further test using the method of example 1 was carried out on Flemion SH80 material using the following laser set-up parameters:

10

Pulse On-Time 25 $\mu$ s  
Maximum Pulse Power 10%  
Minimum Pulse Power 10%  
Laser-Membrane Dist. 25mm  
15 Cutting Speed 35mm/s

The membrane was successfully cut and bonded.

### Example 4

20

Laser cutting and joining of Nafion 115 to a polyvinylidene fluoride substrate was carried out. The laser used was a Coherent Diamond 64 pulsed CO<sub>2</sub> industrial laser (power range 10-150 watts, optimum focal distance 5mm), mounted on a gantry motion  
25 system. Samples of membrane were laid over a flat polyvinylidene fluoride substrate and cut in a straight line using the following laser set-up parameters.

30

Maximum Pulse Power	Minimum Pulse Power	On Time	Cutting Speed	Cut?	Bonded?
10%	10%	25 $\mu$ s	25mm/s	Yes	Yes
20%	20%	25 $\mu$ s	40mm/s	Yes	Yes
35 100%	80%	25 $\mu$ s	1000mm/s	Yes	Yes

Example 5

Laser cutting and joining of membranes to a polyethylene substrate was carried out on the following membrane materials:

5

Fluorinated ethylene-propylene copolymer (FEP)  
film (100 $\mu$ m thick, 100mm wide)  
Nafion 115 (120 $\mu$ m thick, 100mm wide)

10

The laser used was a Synrad sealed, continuous wave CO<sub>2</sub> laser. The trials were performed on a 100mm test piece on a polyethylene board through a galvanometer beam delivery system. The laser used was a 50W unit with one rod disconnected, thus effectively operating as a standard 25W unit. The actual beam power was measured using a calibrated laser intensity meter (the maximum laser power was found to be 30W). The results of the cutting trials are given below:

15

20

Actual Beam Power (Watts)	Cutting Speed (mm/s)	Membrane Material	Comments
30	20	FEP	Cut Weak bond
18	20	FEP	Cut Good bond
18	20	Nafion	Cut Very good bond

25

Example 6

Laser cutting and joining of a rectangular portion of membrane with four curved corners was carried out using a pulsed laser with the following materials and laser parameters:

30

Membrane = Nafion 115 and FEP



Frame material = high density polyethylene  
Laser power = 60W for straight edges  
4W for corners

5 Cutting speed = 100mm/s for straight edges  
40mm/s for corners.

Claims:

1. A method for cutting a fluorinated polymer membrane and simultaneously joining it to a polymer frame, the method comprising the steps of;  
5 (i) contacting a fluorinated polymer membrane with a polymer frame at the point where a cut and join is desired, and  
(ii) directing at least one laser beam onto the  
10 point of contact between the membrane and the frame so as to cut the membrane and effect a join to the frame.
2. A method according to claim 1 wherein the  
15 fluorinated polymer membrane is made from a fluorinated polymer selected from polytetrafluoroethylene, polyhexafluoropropylene, tetrafluoroethylene-hexafluoropropylene copolymer, tetrafluoroethylene-propylene  
20 copolymer, tetrafluoroethylene-ethylene copolymer, hexafluoropropylene-propylene copolymer, hexafluoropropylene-ethylene copolymer, polyvinylidene fluoride, vinylidene fluoride tetrafluoroethylene copolymer,  
25 vinylidene fluoride hexafluoropropylene copolymer, polyvinyl fluoride, tetrafluoroethylene-perfluoroalkyl vinyl ether copolymer, polyvinylidene-hexafluoropropylene copolymer, chlorotrifluoroethylene-ethylene  
30 copolymer, chlorotrifluoroethylene-propylene copolymer, or perfluoroalkoxy copolymer.
3. A method according to claim 1 wherein the  
35 fluorinated polymer membrane is a fluorinated polymer ion exchange membrane.
4. A method according to claim 3 wherein the

- fluorinated polymer ion exchange membrane is made from a fluorinated polymer selected from polytetrafluoroethylene, polyhexafluoropropylene, tetrafluoroethylene-hexafluoropropylene copolymer, tetrafluoroethylene-propylene copolymer, tetrafluoroethylene-ethylene copolymer, hexafluoropropylene-propylene copolymer, hexafluoropropylene-ethylene copolymer, polyvinylidene fluoride, vinylidene fluoride tetrafluoroethylene copolymer, vinylidene fluoride hexafluoropropylene copolymer, polyvinyl fluoride, tetrafluoroethylene-perfluoroalkyl vinyl ether copolymer, polyvinylidene-hexafluoropropylene copolymer, chlorotrifluoroethylene-ethylene copolymer, chlorotrifluoroethylene-propylene copolymer, or perfluoroalkoxy copolymer with suitably functionalised monomer units grafted thereon.
5. A method according to claim 3 or claim 4 wherein the fluorinated polymer ion-exchange membrane is a fluorinated polymer cation-exchange membrane.
6. A method according to claim 5 wherein the fluorinated polymer cation-exchange membrane is a hydrolysed copolymer of tetrafluoroethylene and a perfluoro-vinyl ether monomer comprising a cation-exchange group.
7. A method according to any one of claims 3 to 6 wherein the fluorinated polymer ion-exchange membrane is de-functionalised in the vicinity of the cut edge so as to reduce the wicking of fluid through the cut edge.
8. A method according to any one of the preceding

claims wherein the thickness of the membrane is in the range of from 25 $\mu$ m to 300 $\mu$ m.

- 5 9. A method according to any one of the preceding claims wherein the frame is made from a polymer selected from polyethylene, polypropylene, polystyrene or a copolymer blend of two or more of polyethylene, polypropylene and polystyrene, acetal, nylons, polyethylene terephthalate, 10 polyvinylidene fluoride, polyvinyl chloride, polytetrafluoroethylene, fluorinated ethylene-propylene copolymer, polyfluoramide, or chlorinated polyoxymethylene.
- 15 10. A method according to any one of the preceding claims wherein the laser beam is either pulsed or continuous.
- 20 11. A method according to any one of the preceding claims wherein the power of the laser beam is in the range of from 10 to 150W.
- 25 12. A method according to any one of the preceding claims wherein the speed of travel of the laser beam along the cutting and joining line is in the range of from 10mm/s to 1000mm/s.
- 30 13. A method according to any one of the preceding claims wherein the width of the beam at the point where it impinges on the membrane is in the range of from 50 $\mu$ m to 450 $\mu$ m.
- 35 14. A method according to any one of the preceding claims wherein the laser used is a pulsed CO<sub>2</sub> laser.
15. A method according to any one of the preceding

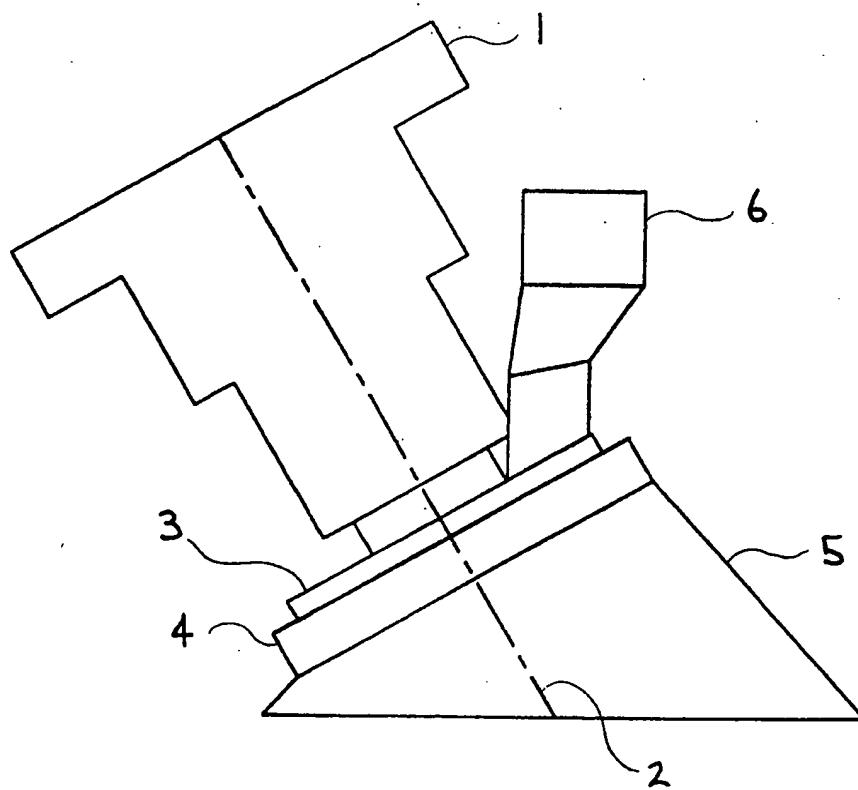
- 5       claims wherein there is provided shielding means which is situated adjacent to the point of contact of the laser beam with the membrane and which moves in synchrony with the laser beam as it travels along the cutting line.
- 10       16. A method according to any one of the preceding claims wherein the contact between the fluorinated polymer membrane and the hydrocarbon polymer frame is achieved by pressure means which urges the membrane into contact with the frame.
- 15       17. A method according to claim 16 wherein the pressure means comprises a plate of substantially the same perimeter size and shape as the membrane which can be pressed against the membrane to ensure contact between the membrane and frame at the point of cutting.
- 20       18. A method according to claim 16 wherein the pressure means comprises a roller which impinges on the membrane at a position adjacent to the laser beam.
- 25       19. A method according to claim 16 wherein the pressure means comprises one or more gas jets which apply positive air pressure on the membrane at a position adjacent to the laser beam.
- 30       20. A method according to claim 19 wherein the laser beam and gas jet are directed at an angle of from 110 to 120 degrees to the plane of the membrane, pointing in a direction away from the centre of the membrane.
- 35       21. A method according to claim 16 wherein the pressure means comprises means for providing a

vacuum between the membrane and the frame at or adjacent to the point where the laser beam impinges on the membrane.

- 5      22. A method according to any one of claims 16 and 18  
to 21 which additionally utilises a plate of  
substantially the same size and shape as the  
membrane which impinges thereon and acts as a  
shield to prevent debris from the cutting  
10      procedure from contaminating the main central  
portion of the membrane.
23. A method according to any one of the preceding  
claims wherein the laser beam is in the form of a  
15      single beam, dual beams or concentric multiple  
beams.
24. A method according to any one of the preceding  
claims wherein the membrane comprises an  
20      electrode attached thereto.
25. Apparatus for cutting a fluorinated polymer  
membrane and simultaneously joining it to a  
polymer frame, the apparatus comprising a beam  
25      delivery system which comprises means for  
generating and directing one or more laser beams  
onto the membrane and means for generating and  
directing positive air pressure to a point at or  
adjacent to the point where said one or more  
30      laser beams impinge on the membrane.
26. Apparatus as claimed in claim 25 which  
additionally comprises a cowl which encompasses  
the laser beam delivery area and a pump for  
35      conveying fumes away from the point of cutting  
and sealing.

27. Apparatus as claimed in claim 26 wherein the pump and the beam delivery system are mounted upon a central boss, said boss being housed within a bearing on which the main body of the cowl may be mounted.
- 5
28. Apparatus as claimed in any one of claims 25 to 27 wherein the means for generating and directing one or more laser beams and the means for generating and directing positive gas pressure are constructed so as to provide a laser beam and a gas jet which are substantially parallel to one another.
- 10
29. A sub-assembly comprising a polymer frame and a fluorinated polymer membrane which has been cut and joined thereto by the method claimed in any one of claims 1 to 24.
- 15
30. An electrochemical apparatus formed from a plurality of sub-assemblies as claimed in claim 29.
- 20

Fig.1





# INTERNATIONAL SEARCH REPORT

Int. Application No  
PCT/GB 99/02335

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01M8/02 H01M10/02 H01M2/18 C25B13/00 B01D65/00  
B01D63/08 H01M8/10 B23K26/14 B23K26/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01M C25B B01D B29C B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 772 817 A (YEN YUNG-TSAI ET AL) 30 June 1998 (1998-06-30)  column 6, line 28 - line 45; figure 4 claims 1,7-12,16 column 2, line 66 -column 3, line 11 column 5, line 40 - line 55 column 6, line 3 - line 26 ---	1,2,10, 11,14, 16,23,29
X	DE 92 15 287 U (WISSNER ROLF) 4 March 1993 (1993-03-04) page 8, last paragraph -page 9, paragraph 1; claim 1; figures 1,2 ---	25,26,28
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

15 December 1999

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

D'hondt, J

# INTERNATIONAL SEARCH REPORT

International Application No

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X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 305 (M-0992), 29 June 1990 (1990-06-29) & JP 02 099292 A (SHINKO KOGYO CO LTD), 11 April 1990 (1990-04-11) abstract ---	25,26
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PCT/GB 99/02335

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	<p>PATENT ABSTRACTS OF JAPAN vol. 018, no. 396 (M-1644), 25 July 1994 (1994-07-25) &amp; JP 06 114943 A (MITSUBISHI HEAVY IND LTD), 26 April 1994 (1994-04-26) abstract -&amp; DATABASE WPI Derwent Publications Ltd., London, GB; AN 94-173240 XP002094742 abstract</p> <p style="text-align: center;">---</p>	1
A	<p>US 5 645 665 A (SALAZAR MIKE A ET AL) 8 July 1997 (1997-07-08) column 1, line 47 - line 60</p> <p style="text-align: center;">---</p>	1
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